Insects, mites, and molds in farm-stored grain in the Prairie Provinces

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Insectes, acariens et moisissures nuisibles aux grains entreposés à la ferme dans les provinces des Prairies

CONTENTS

GOOD STORAGE PRACTICES

You can prevent losses from insects, mites, and molds by storing your grain properly.

- Harvest grain as dry as possible. Tough or damp grain is more likely to heat and become infested than is dry grain.
- Before storing the new crop prepare the granary by sweeping the floor and walls, burning or burying sweepings that contain spoiled or infested grain, repairing the building to make it weatherproof, and spraying the walls and floors with a recommended insecticide.
- Examine stored grain every 2 weeks for signs of heating or infestation. During winter, control heating or infestations by moving the grain to another bin. If this is not possible, the installation and proper use of natural air ventilation systems are strongly recommended. Fumigants should be applied only by experienced people. Observe precautions during application of insecticides.
- Preventing infestations is easier, safer, and less expensive than controlling them.
- Recommendations for pesticide use in this publication are intended as guidelines only. Any application of a pesticide must be in accordance with directions printed on the product label of that pesticide as prescribed under the *Pest Control Products Act*. Use a pesticide registered by Agriculture Canada and listed in the *Compendium of Pest Control Products Registered in Canada*. A pesticide should also be recommended by provincial authorities. Because recommendations may vary from province to province, consult your provincial agricultural representative for specific advice.

Insects, mites, and molds in farm-stored grain in the Prairie Provinces

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INTRODUCTION

Protecting stored grain from spoilage is an essential part of grain production. Insects and mites eat stored grain, cause it to heat, and spoil its appearance. Infested grain is hard to sell, and heated grain is downgraded by inspectors. Losses in weight and quality are a high price to pay for failing to protect grain from infestations. These losses can usually be prevented by storing grain as dry as possible in clean, weatherproof, uninfested, and preferably aerated granaries. Such practices maintain the quality of the grain and ensure its salability.

The insects and mites that attack stored grain vary in appearance and behavior from those that infest growing crops. They are mostly small, light-avoiding pests that are capable of penetrating deeply into bulks of stored grain. In empty granaries, they hide in cracks and crevices where they can survive in grain residues until they infest newly harvested grain. Stored-grain pests feed on dried animal and vegetable matter. Some may survive on food that contains as little as 8% moisture, and some may tolerate extreme temperatures. The cold-hardy insects are particularly widespread because some of them can survive the winter in stored grain. During summer, some insects fly and may be carried by the wind to granaries and even into houses.

*Retired

Stored grain also contains storage molds or fungi that can attack stored grain and cause spoilage. Molds develop rapidly in grain that is stored either in a tough or damp condition in warm weather. Under certain conditions of harvest and storage, some fungi may produce poisonous by-products called mycotoxins.

COMMON PESTS OF STORED GRAIN

More than 50 species of insects and mites have been found in stored grain in the Prairie Provinces. Fortunately, only a few of these cause serious damage. The others are fungus feeders, scavengers, predators, and parasitoids.

Beetles and moths are the most damaging pests of stored grain. They have four life stages: egg, larva, pupa, and adult.

The eggs are either laid within or inserted in the crevices of a grain kernel, between kernels, or in grain dust and waste grain in floor and wall cracks.

The larva is the only stage during which the insect grows, and it consumes several times its own weight in food. Since the larval skin cannot stretch, it splits and is cast off periodically to allow the larva to increase in size. Larval skins found in grain and grain products are often the only visible signs that insects are present.

The pupa, which forms after the last larval molt, does not feed. In some beetle species, the pupa is enclosed in a cell, or cocoon, constructed by the larva. During the pupal stage, the insect undergoes extreme internal and external changes that lead to the development of the adult.

Adults of the most damaging stored-grain insects are 0.1–0.4 cm long. The adult has three pairs of legs and its body is divided into three parts: head, thorax, and abdomen. The head contains mouthparts and sense organs; the thorax comprises legs and wings; and the abdomen contains the reproductive organs. Adults move in the spaces between kernels and can penetrate deeply into a pile of grain.

Some insects can fly and have a wide distribution. Beetles, however, have poorly developed wings and many species are unable to fly. Notable exceptions are the rusty grain beetle and the red flour beetle. Adults and larvae of some beetles have strong jaws that enable them to feed on broken grain and chew holes in grain kernels. Adult moths can feed only by sucking fluids, but moth larvae have strong jaws that can cause extensive damage by feeding on stored grain.

Mites are the smallest of the pests that invade stored grain. Adults of the most common stored-grain mites are 0.3–0.6 mm long and have four pairs of legs.

Many of the storage pests that occur in the Prairie Provinces can survive winter temperatures. Insects cannot reproduce at temperatures below about 17°C and mites at below 3°C, but when grain temperatures are higher, storage pests can do extensive damage. The moisture content of grain also influences the extent to which insects and mites infest grain and cause it to heat and spoil. Grain that has been assigned a straight grade is less prone to spoilage than grain that has been graded tough or damp (see Table 1, p. 15).

Fig. 1 Wheat damaged by stored-grain insects: *A*, undamaged kernel; *B*, germ damaged by the rusty grain beetle; *C*, germ damaged by red flour beetle; *D*, germ damaged by saw-toothed grain beetle; and *E*, endosperm damaged by granary weevil.

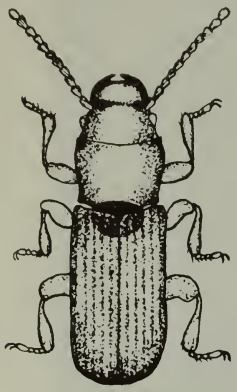
The most destructive storage pests in the Prairie Provinces are cold-hardy, have high reproductive rates, can penetrate to great depths in stored grain bulks, and can readily adapt and establish themselves in a wide variety of foods.

The insects that infest farm-stored grain in the Prairie Provinces are rusty grain beetles, several species each of flour beetles and fungus beetles, saw-toothed grain beetles, granary weevils, hairy spider beetles, and meal moths. Grain mites also commonly occur in stored grain, but because of their microscopic size they are often unnoticed. Descriptions of the most common pests follow (see diagrams).

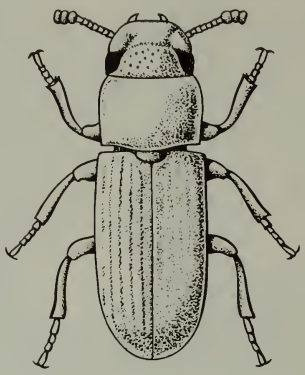
Beetles

The rusty grain beetle is the most serious pest of stored grain in most regions of Canada. Heavy infestations of this insect cause grain to heat and spoil. The adult is a flat, rectangular, reddish brown beetle, 0.2 cm long, and has long threadlike antennae that project forward like a V. It moves rapidly in warm grain and can fly when the air temperature is above 23°C. Eggs are laid in grain and grain dust and in the crevices of kernels. The tiny larvae feed on and then penetrate the germs of sound kernels. In about 20 days, eggs become adults in wheat at 14.5% moisture content and 31°C.

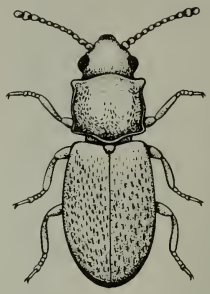
The red flour beetle has been reported more often in stored grain since 1971 than in previous years. Serious infestations have occurred in farm-stored grain and in country elevators at various locations throughout the Prairie



Rusty grain beetle
Length 0.2 cm



Red flour beetle
Length 0.4 cm



Foreign grain beetle
Length 0.25 cm

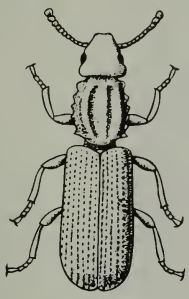
Squarenosed fungus beetle
Average length 0.18 cm

Provinces. The adult, which resembles the confused flour beetle, is reddish brown and 0.4 cm long. However, the confused flour beetle is rarely found in stored grain. The two species are difficult to distinguish without the aid of a magnifying glass or microscope. Red flour beetles can fly in warm weather or may be blown by the wind into farmhouses and other buildings. The larvae and adults of both species feed on the germ of wheat kernels and on grain dust and dockage. They complete development from egg to adult in about 4 weeks under optimal conditions of 31°C and 15% moisture content.

The American black flour beetle is somewhat larger than the red flour beetle. It is found occasionally in empty granaries but does not usually infest stored grain.

Fungus beetles usually infest tough or damp grain by feeding on grain dust and molds that grow near the grain surface. Dry grain stored next to tough or damp grain may also become infested. Because certain species of fungus beetles resemble the rusty grain beetle and are about the same size, control measures are often needlessly applied. Therefore, insects should be correctly identified before chemical control measures are applied. The foreign grain beetle and the squarenosed fungus beetle are the most common fungus-feeding insects found in stored grain in the Prairie Provinces.

Producers or grain handlers should be as concerned about fungus beetles in stored grain as they are about the rusty grain beetle, because the presence of fungus beetles indicates that molds and high moisture are present and that the grain may be going out of condition. If measures to move the grain are not taken, all or most of the grain may spoil resulting in significant losses.



Sawtoothed grain beetle
Length 0.3 cm

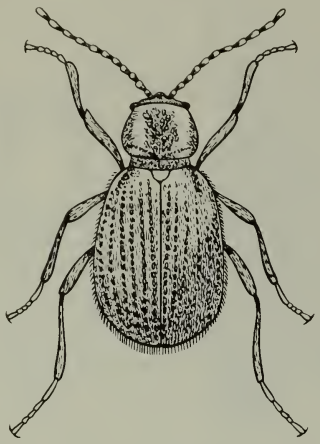
Granary weevil
Length 0.35 cm

Controlling fungus beetles by fumigation will not stop grain spoilage by molds. If fungus beetles are present, the grain must be turned to break up tough or damp pockets.

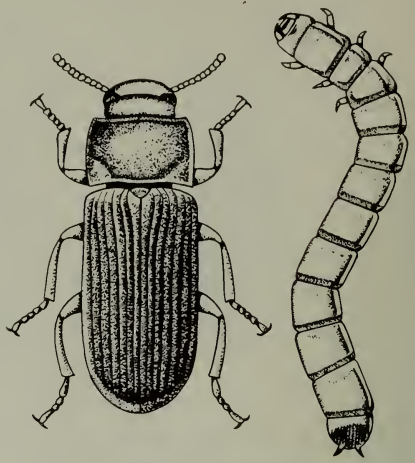
Sawtoothed grain beetles are more common in stored oats than in stored wheat and barley. The insect is capable of increasing its numbers rapidly in large bulks of grain and in animal feeds stored in heated premises. They cause grain to heat and can survive the winter in grain dust and tough grain. The adult is brown, about 0.3 cm long, and has six toothlike projections on each side of the thorax. It is active in warm grain and takes about 22 days to complete development from egg to adult under optimal conditions, 31–34°C and 14–15% moisture content.

The granary weevil is one of the most destructive pests of stored grain in the world. It is rare in the Prairie Provinces. The adult has a distinctive snout, which it uses to bore holes in grain kernels. The female deposits a single egg in a hole in each kernel and then seals the opening with a gelatinous fluid. The larva feeds on the endosperm, and completes its development within the kernel. The pupa that is formed transforms into an adult that chews a hole in the side of the kernel and emerges. Development from egg to adult takes 25–35 days under optimal conditions of 26–30°C and 14% moisture content. The dark brown weevil is about 0.3–0.4 cm long. When disturbed, it folds its legs under its body and appears to be dead.

In recent years, the rice weevil has been found in some elevators. It is 0.2–0.4 cm long and has four distinct reddish orange spots on the wings, which are folded over the abdomen. It completes development from egg to adult in 28 days at 30°C and 14% moisture content.



Hairy spider beetle
Length 0.35 cm



Yellow mealworm and adult
Length of adult 1.5 cm

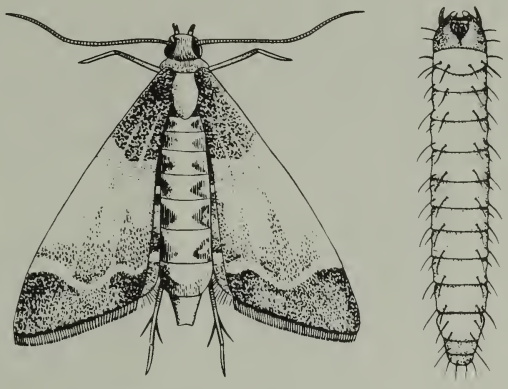
The hairy spider beetle is mainly a pest of wheat flour and animal feeds, but it may also infest some stored grain near the surface. Adults and larvae have strong jaws with which they chew large irregular holes in the endosperm of kernels. The adult is 0.35 cm long and has long spiderlike legs and long thin antennae. This beetle has only one generation a year. Three or four larvae often cement five to eight kernels together to form a cluster, where they feed and grow for up to 5 months, and then each constructs its own pupal cell. The pupa forms within the cell and emerges as an adult.

Yellow mealworms are the largest insects found in stored grain. They are not common pests on farms but large numbers sometimes occur on the grain surface. Yellow mealworms first infest animal feeds and then move into stored grain. The adults are black beetles about 1.5 cm long; the larvae are yellow and 0.2–2.8 cm long. Yellow mealworms prefer dark, damp places in a granary or feed warehouse. The adults live for only 2–3 weeks, but the larvae may take several months to change into pupae.

Moths

In the Prairie Provinces, moths infest farm-stored grain to a lesser extent than beetles. Low temperatures in winter control moth infestations, which are confined mainly to the surface layers of tough or damp grain that may be heating.

Meal moths usually occur in patches of moldy grain. The larvae are cream-colored, have black heads, and are about 2 cm long when full-grown.



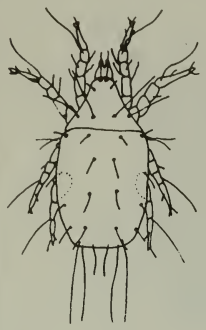
Meal moth and larva
Adult wingspread 2.5 cm

They produce a silklike substance that webs the kernels together in clumps. The moth has a wingspread of 2.5 cm. The fore wings are light brown, with dark brown patches at the bases and tips. Each wing has two wavy, white stripes. The life cycle takes about 2 months to complete in summer.

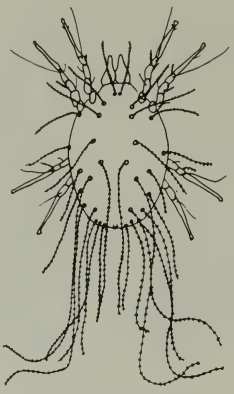
Mites

Grain mites are tiny, fragile creatures that are hard to see with the naked eye. Unlike an adult insect, which has a distinct head, thorax, and abdomen and six legs, an adult mite has a saclike body with eight legs. It can withstand low temperatures in winter, feed on broken grain, weed seeds, dockage, and mold found in bulk grain and is therefore well adapted for infesting stored grain and oilseeds in the Prairie Provinces. Tough and damp pockets of cereals and rapeseed (canola) are favorite breeding places for mites. About 25% of such seed may be infested with mites. About eight kinds of mites are common in farm granaries and elevators. They give a strong minty odor to infested grain. Their life cycle is composed of the egg stage, the six-legged larva stage, 2–3 eight-legged nymphal stages, and the eight-legged adult stage. One of the developmental stages can change into a nonfeeding hypopus stage that could be mobile or inert and is resistant to low winter temperatures, drying, starvation, and most fumigants.

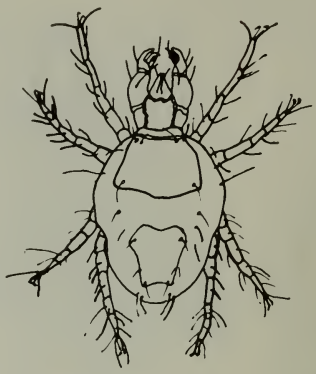
The grain mite attacks the germ of cereals causing germination loss, and spreads fungi (molds), which are also eaten. Heavily infested grain becomes tainted and unpalatable as animal feed. In some cases, dairy cattle and other



Grain mite
Average length
0.45 mm



Longhaired mite
Average length
0.4 mm



Cannibal mite
Average length
0.5 mm

Glossy grain mite
Less than
0.2 mm long

farm animals develop gastric disorders and other symptoms after eating mite-infested feed.

Adults are 0.3–0.6 mm long and females are larger than males. This mite is pearly white to yellow brown and has a smooth, glistening body with four long hairs arising from the rear end. The grain mite can build up large populations increasing up to sevenfold in 1 week in stored grain, particularly in the fall. Adult females can lay about 500 eggs during a life-span of 42 days. The grain mite can develop from egg to adult in 14 days at 20°C and 14% moisture content. Adults and all immature stages except the hypopus stage die in about a week when exposed to -18°C. Eggs can survive exposure to -10°C for about 12 days or 0°C for 2–3 months.

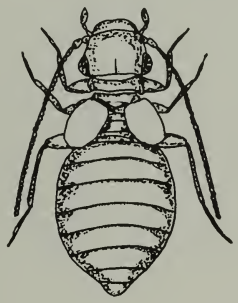
The longhaired mite is the most common kind of storage mite. It is cold-hardy and can live in both straight grade and tough grain. It has many stiff hairs that are longer than its body. It moves rapidly with a jerky gait, and feeds on broken grain, grain dust, and fungi. The adult is white and about 0.3–0.5 mm long. In farm granaries, chronic infestations of this mite generally occur between June and November. It can survive for more than 7 days at -18°C.

The cannibal mite feeds on the grain mite, the longhaired mite, and insect eggs. Unfortunately, cannibal mites are not abundant enough to eliminate all the mite pests that damage grain. They have a diamond-shaped, white body with a chalky white line running the length of the body and pincerlike grasping organs, palps, and long legs. They are 0.4–0.6 mm long. Cannibal mites are active in bulk grain in all seasons, usually in low numbers. In most tough grain they can breed at 12–27°C.

The common, fungus-feeding glossy grain mite is found in aging farm-stored grain. It completes development from the egg to the adult stage in 7 days under optimal conditions of 30°C and 17% moisture content. Its populations build up in stored wheat corresponding to growth of certain storage fungi on which it feeds. Its presence indicates that the grain is becoming moldy and going out of condition. The adult is clear orange or yellowish and less than 0.2 mm long. It can live for about 17 days at 30°C and 90% relative humidity.

Psocids

These insects are slightly larger than grain mites. The adult is soft-bodied and about 0.1 cm long. It has a large head and long antennae, and some species have wings. The female lays about 100 eggs in 3 weeks and these eggs develop into adults during the summer. The period of development from egg to adult is about 21 days at 27°C and 13% moisture content and some adults can live for 51 days without feeding. Psocids are not important pests of stored grain, although they can feed on damaged kernels and are found in tough or damp grain. They are usually found with other insects or mites that are more serious pests of stored grain, often feeding on their eggs.



Psocid
Length 0.1 cm

Molds (storage fungi)

These organisms originate from the soil and decaying plant material. They occur in combines and as spores on stored seeds. Storage fungi are usually inactive at low seed-moisture contents. However, when the moisture content increases, as it does in tough, damp, or accidentally wetted seeds, the spores germinate and different types of mold develop in a definite succession. The first fungus to develop produces moisture that allows other fungi in the succession to germinate. The rate of fungal growth is dependent on seed moisture and temperature. Development of storage fungi on seeds may affect seed quality by causing heating and spoilage, packing or caking effects, reduced germination, and production of off-odors.

Mycotoxins

Mycotoxins are fungal products that are poisonous to some farm animals and other higher forms of life. Toxin-producing strains of *Aspergillus* and *Penicillium* species often grow on stored grain under favorable conditions of temperature and moisture to produce these mycotoxins. Because of high ambient temperature and humidity, such toxins are more of a problem in tropical countries than in the Prairies. Mycotoxins have occasionally been found in areas of Canada where higher humidities prevail.

Mycotoxins, when they do occur, are present at low concentrations, and are detectable only by lengthy and complex chemical analysis. Their specific toxicity is high, and the health of farm animals can be affected at the parts per million level, or less. In cases of acute poisoning due to moldy feed, large numbers of animals may be prostrate or dying; during chronic poisoning cases, diminished livestock productivity is observed. Farmers suspecting mycotoxin poisoning should consult their veterinarians.

Stored grain often becomes contaminated with blue-green *Penicillium* molds through accidental dampening or incorrect storage, and toxigenic strains of this fungus may be encountered. Resulting contamination by ochratoxin A, a potent kidney toxin, has been observed in damp wheat and barley. It is advisable not to feed animals, especially swine and poultry, grain that is suspected of being contaminated by this toxin.

CAUSES OF GRAIN SPOILAGE AND INFESTATIONS

Grain that has been harvested tough or damp may heat and become infested with insects or infected by fungi during storage. Bumper crops and low delivery quotas may force farmers to store grain in temporary storages such as open cribs, barns, machinery sheds, and uninhabited houses. If the grain cools uniformly during the winter it will not spoil. But if it is stored in a bin that holds more than about 30 t, moisture may condense at the surface or sides, spoilage organisms may develop, and insects may thrive and reproduce.

Even when grain has been stored in a dry condition, moist spots may develop. Patches of grain become moist when water vapor moves in convection currents of air from warm to cool grain. Wet patches also form in the grain when rain or snow gets into the granary through ventilators and cracks in the roof and walls. In most cases, the drying action of the prairie winds reduces the risk of damage. But high-moisture grain is always subject to spoilage, and constant attention is required to prevent the conditions that cause grain to deteriorate.

Grain is often binned at high temperatures during warm harvest weather or after it has been dried. Because grain is a good insulator (one-third that of cork), it cools slowly. Parts of the grain, particularly the central part, may remain warm for several weeks during fall and early winter. Under these conditions, the surface and outside layers of the grain cool rapidly, and moisture in the central part moves through the intergranular spaces, condenses on the cooler surface grain, and causes it to germinate. Storage fungi, which are always present, grow and produce heat whenever conditions are favorable for them.

High moisture content in stored grain is an important factor that leads to grain spoilage (Table 1).

Table 1. Percentage of moisture content of tough or damp cereal grains, oil seeds, and legumes*

	Percentage of moisture content	
	Tough	Damp
Wheat	14.6–17.0	over 17.0
Amber durum	14.6–17.0	over 17.0
Buckwheat	16.1–18.0	over 18.0
Oats	14.1–17.0	over 17.0
Barley	14.9–17.0	over 17.0
Flaxseed	10.6–13.5	over 13.5
Canola (Rapeseed)	10.1–12.5	over 12.5
Mustard seed	10.6–12.5	over 12.5
Rye	14.1–17.0	over 17.0
Peas	16.1–18.0	over 18.0
Corn	15.6–17.5	17.6–21.0
Soybeans	14.1–16.0	16.1–18.0
Sunflower	9.6–13.5	13.6–17.0

**Source*: *Grain grading handbooks for Western and Eastern Canada*. 1 August 1980. Canadian Grain Commission, Winnipeg, Man.

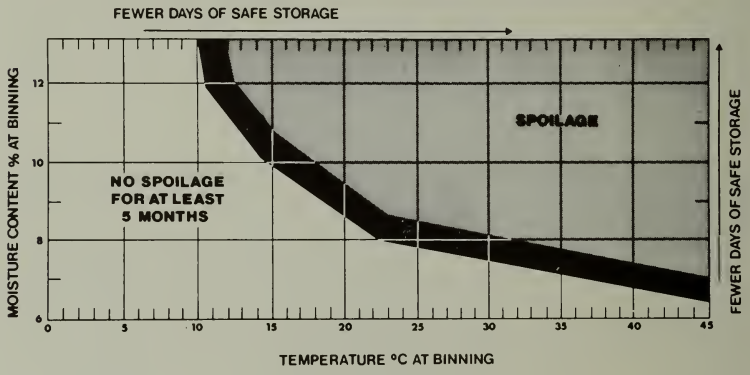
Grain that has been graded tough or damp requires more attention than straight-grade grain in order to prevent spoilage. It is subject to loss in grade when delivered to the elevator, because it must be dried to straight grade before it can be put into commercial export channels. High-moisture grain

must be placed in special bins and shipped separately. Such grain is also more susceptible to infestation than straight-grade grain.

In the following canola storage time chart a spoilage-free 5-month storage period for various combinations of temperature and moisture content is predicted.*

The insects, mites, and molds that cause grain to heat and lose condition are inactive at low temperatures (below about 8°C for insects, 0°C for mites, and –8°C for molds). Tough and damp grain stored in bulks of less than 30 t usually cools rapidly and evenly during winter. The surface also dries to a certain extent. But a bulk larger than 30 t cools more slowly, and temperature differences between the center and the surface may cause condensation and spoilage.

CANOLA STORAGE TIME CHART*



TYPES OF STORAGE, AND PREVENTION OF SPOILAGE, STORAGE FUNGI, AND INFESTATIONS

Well-constructed granaries are essential to prevent infestations and preserve grain quality during long-term storage. The best granaries are weatherproofed, ventilated, and of single-wall construction. Several 27-t granaries are better than a few larger ones, because small bulks cool faster and more evenly than large bulks. Granaries should be built on high, well-drained land to protect the grain from heavy rainfall and spring floods. All types of granaries have advantages and disadvantages for storing grain.

Steel granaries provide fewer places for insects to breed than wooden granaries do. They can also be made rodent-proof, and require far less maintenance than wooden granaries. Infested grain can be fumigated more effectively in tightly constructed granaries.

*Source: *Canola farming*. Fact sheet No. 4. 1980. Canola storage. Canola Council of Canada.

Most steel granaries are erected on reinforced concrete slabs that sometimes crack and allow ground moisture to seep into the grain. The sides of the granary expand when the granary is filled with grain, and all open seams, especially at the base, must be waterproofed. Use a caulking compound to fill all the cracks in the floor and also the open spaces where the floor and walls are joined. The concrete pads should be shaped slightly convex to shed water. Depressions in the pad hold water, which is absorbed by the grain. Granaries should not be filled to the spout. Ample head room should be left above the surface of the grain for ventilation and drying.

Grain producers are switching to large-capacity metal bins for storage purposes. Because problems with moisture migration may occur in these bins, it is strongly recommended that aeration systems be installed to reduce the risk of spoilage and insect or mite infestations during storage.

Most small wooden granaries hold about 27 t of wheat and can usually be moved when they are empty. Old wooden granaries require frequent repairs to keep them weatherproof. Raise the granaries about 15 cm above the ground to allow the air to circulate underneath and to cool the grain uniformly.

Grain is often stored in barns, machinery sheds, and houses when crop yields are above average. Take extra precautions to prevent grain spoilage if you use these types of storage. Fill the cracks in concrete floors with a caulking compound. The double walls in barns often contain infested grain dust. Remove the bottom boards to clean out the debris and apply insecticide sprays or dusts in the spaces between the studs.

You can use either plywood or bales of hay to construct open cribs for temporary grain storage. Locate cribs on high, dry land to avoid losses from ground moisture. Cone the grain as high as possible at the center to shed rain and snow and to avoid a space between the top edge of the crib and the grain surface. Use a dark polyethylene sheet to cover dry grain, but leave tough or damp grain uncovered to promote the drying of grain by the wind.

Prevention of spoilage by air circulation

In the cool climate of the Prairies, the quality of grain and oilseed can be maintained economically by forcing natural air through bulk-stored crops. This is accomplished by blowing in or sucking out air with low airflow rates by means of an axial (or centrifugal) fan attached to a bin equipped with either a perforated duct or a perforated floor. As long as a fan provides an airflow rate of at least 1 L/s (1 litre per second) per cubic metre the grain will be cooled and its temperature and moisture content maintained at a reasonably uniform level. The forced air will reduce moisture migration by decreasing temperature gradients throughout the bulk. When warm air is blown in with a fan immediately after harvest in late summer or fall, the warm outside air will reduce the moisture content of the grain by at least 1% or 2%. For some crops, such as canola (rapeseed), even a minimal amount of grain drying can make the difference between safe crop storage and serious spoilage. Stored canola can spoil quickly, even when the seed is binned at or near straight grade moisture levels. Crop spoilage in storage can be prevented with a relatively small fan. The smaller the fan size the lower will be the costs of energy and initial installation.

As soon as the grain is put into the granary, the fan should be turned on to blow outside air in and allowed to run until the grain temperature is lowered to the level of night temperature. The temperature of grain harvested on a hot day is usually 6–8°C higher than the air temperature. It will be advisable to run the fan in conjunction with a humidistat to conserve electrical energy and regulate moisture reduction. When operated manually, the fan should be switched off during prolonged rainy and foggy days. Insects, mites, and fungi that cause spoilage usually begin their multiplication in a small pocket of tough or damp grain within an otherwise straight-grade grain bulk. This is why it is risky to let too much damp air into the bin during wet days.

When the air temperature drops to near 0°C, the airflow should be reversed. By reversing the airflow, the outside air will only chill the grain but not remove any moisture from it. When the air is blown in, the last part of the bulk to cool and dry will be the top layer. It is easy to check from the top to determine whether the whole bulk is cooled or spoilage has begun. In both fall and winter, most grain spoilage begins near the top center of the bulk where moisture condensation is greatest. When the air is sucked out by reversing the airflow, the last part to cool is the bottom layer. In this case there is less chance of high moisture condensation and spoilage near the top center.

Prevention and control of storage fungi

To prevent storage mold activity, particular attention should be given to the moisture and temperature of the bulk at binning, especially in unaerated bins. Seed temperatures should be monitored at intervals. High-moisture and/or high-temperature grain should be dried or cooled by aeration (see previous section). A spreader should be used to disperse small particles of broken and shriveled kernels, weed seeds, chaff, and straw within the bulk. Windblown snow should be removed as this can later provide a focus for mold development. To control heating or spoilage in progress, seeds may be turned to break up high-moisture pockets and to cool the bulk. Alternatively, the bulk could be aerated or dried. When climbing into or onto granaries, always have someone with you. If it is necessary to break up a moldy crust within a bin or to handle spoiled grain, wear a protective mask to prevent inhalation of mold spores.

Prevention of insect infestations

If we know where and when insects are likely to occur, it should be easy to control them and prevent infestations. Surveys have shown that most empty granaries are infested with insects and mites. Animal feeds, trucks, and farm machinery are other sources of insect infestations. Some insects can fly as well as walk, and this increases their ability to infest stored grain. Measures to prevent infestation and spoilage of stored grain should start before the grain is harvested.

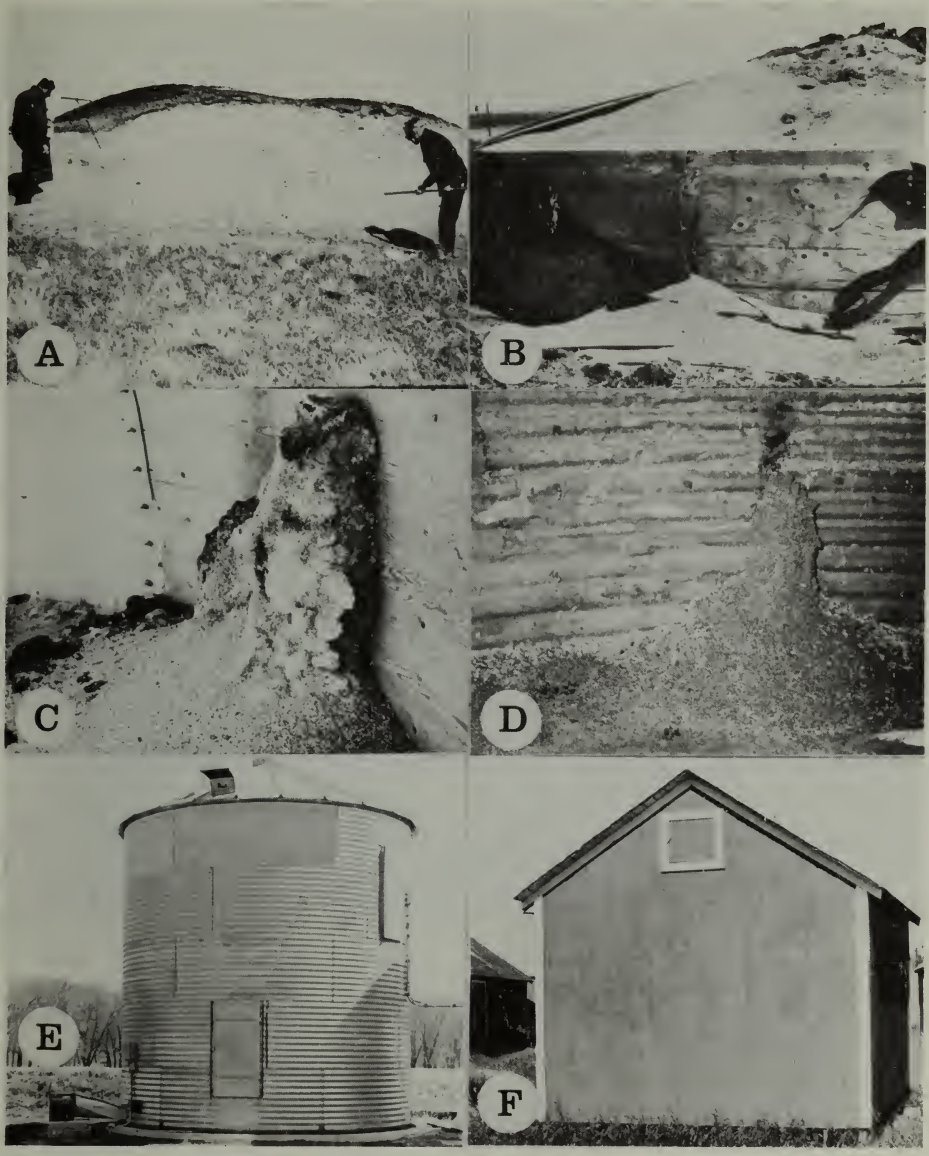


Fig. 2 Different types of storage: *A*, open pile (note crusting at surface); *B*, open plywood bin; *C*, rotting grain near seam on inside of plywood bin; *D*, rotten grain at seam inside steel bin; *E*, steel bin equipped with aeration system; *F*, well-constructed wooden granary.

Fig. 3 Preparing a granary for storage: *A*, gathering sweepings from floor and wall; *B*, collecting sweepings; *C*, disposing of sweepings by burying them in the ground; *D*, disposing of sweepings by burning them; *E*, measuring insecticide; *F*, spraying wall (floor is sprayed the same way). Note mask and gloves.

- Keep grain dockage to a minimum by controlling weeds in the growing crop. Insects do not do as well in grain that contains low amounts of grain dockage.
- Harvest grain as dry as possible because insects, mites, and molds increase rapidly in tough grain.
- Clean, repair, and weatherproof empty granaries. Burn or bury infested sweepings.
- Do not allow waste grain or feed to accumulate either inside or outside of grain storage structures.

- Eliminate grass and weeds around granaries.
- Do not store grain in bins next to animal feeds that are likely to be infested.
- Spray the walls and floor of the empty granary with an approved insecticide about 5 days before storing the grain.
- Fill granaries only to the top plates to provide crawl space and ventilation.
- If grain has been binned tough, examine it every 2 weeks by pushing your hand into the surface at various points to feel for warmth and crusts of grain. Cool, dry grain seldom spoils. Insert a metal rod into the grain to test for crusting at various depths. After about 2 min., withdraw the metal rod and test for warmth on the wrist or palm of the hand.
- Always store new grain in clean bins; bins that contain old grain might be infested.

Prevention of mite infestations

- Keep the moisture content of cereal grain below 12%, and canola below 8%.
- Transfer the grain to an empty bin or condition it by natural air ventilation to break up pockets of grain of 15–16% moisture content.

DETECTING INFESTATIONS

It is important to inspect your grain stocks regularly to detect the first signs of infestation or spoilage. Sample the grain every 2 weeks to check for insects and heating.

To check for insects, use a No. 10 sieve (4 meshes per centimetre) to screen samples from the surface. Use a sampling probe to obtain deep samples. Warm the siftings for a few minutes and then examine them for insect movement. Check grain for heating by feeling the surface grain and inserting a metal pipe below the surface.

To check for mites, sift the grain samples through a No. 30 mesh sieve (12 meshes per centimetre). Warm the dust and screenings to room temperature and examine them through a magnifying glass. Large numbers of mites in grain siftings look like clumps of moving dust. Smaller numbers are harder to see.

Insect-detection devices used to trap insects consist of probes, or pipes, perforated with small holes that will exclude grain kernels but allow insects to drop into the trap. During the summer, plastic cups filled with water may be placed at the top of the grain bulk to trap insects.

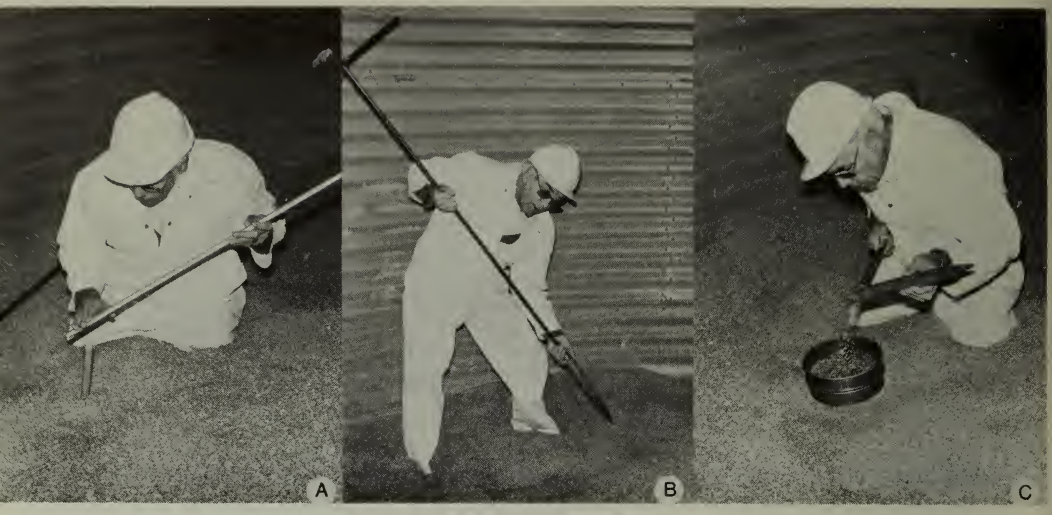


Fig. 4 Inspecting the grain: *A*, steel rods used for locating hot spots; *B*, a torpedo probe is used for sampling the grain; and *C*, emptying grain samples into a sieve to sift out the insects.

CONTROLLING INFESTATIONS

To keep infestations from spreading to other granaries, control them as soon as they are discovered. The type of control treatment depends on the condition of the grain, grain temperature, kinds of insects or mites present, and the time of year.

Cold weather treatment and sanitary measures

An effective method to control insect infestations is to lower the temperature in winter by (1) transferring infested grain from one granary to another; (2) transferring part of the grain to a truck, leaving it to cool overnight and then returning it to the granary; or (3) using aeration systems to lower the temperature. Insects do not develop or feed at temperatures below 10°C. At temperatures below freezing, the insects will die eventually. Control of the rusty grain beetle will be obtained after 2 weeks at a grain temperature of −15°C, after 4 weeks at a grain temperature of −10°C, or after 6 weeks at a grain temperature of −5°C. Since the rusty grain beetle is the most resistant species to low temperature, most other insects in stored grain will also be controlled by these combinations of temperature and exposure periods. If an aeration system is used in winter to lower the temperature, it should be used again in the spring to raise the temperature to within 10°C of outside air temperature. This practice will minimize grain sweating.

Cleaning the grain also checks infestations. To control surface infestations of moths, mites, and spider beetles, rake the grain to break up the crust and dry the grain. Remove and destroy webbed and infested patches of grain.

Contact insecticide treatments

Insects that infest empty granaries must be controlled to prevent spoilage of newly stored grain. Insecticide sprays are part of the good storage practices needed to protect stored grain from spoilage. Use only insecticides that have been approved for use in granaries and take precautions in their handling and use (see section on Cautions). Only approved insecticides can be used because they have been selected on the basis of low mammalian toxicity/high insect toxicity; freedom from taint or odor on food; non-persistent environmental effects; safe, economical, and easy use; and negligible residues or toxic products in food. Because recommended insecticides and application rates can change each year, consult your local agricultural representative for current information.

Insecticide sprays and dusts act only on contact with insects and do not penetrate piles of grain or dust on floors. Therefore, grain residues must be removed from the granary before insecticide application.

Insecticides are available in different formulations and each has a specific use according to the type of granary to be treated.

Dissolve emulsifiable concentrates of insecticides with water to form a milky emulsion and spray it on metal and wood surfaces. Use fresh water to make emulsion sprays and apply the spray immediately after mixing to avoid separation of the insecticide from the water. Emulsifiable concentrates of the insecticides recommended break down more rapidly, and are less effective, on concrete and brick surfaces than on wood or steel. Most insecticides break down within a few days on concrete but can remain effective for up to a year on wood or steel. Do not use these sprays near electrical switches or fuse boxes.

Mix wettable powder insecticides with fresh water in a separate container before filling the sprayer. Wettable powder sprays can be applied to concrete, brick, metal, or wood surfaces. Wettable powders applied on painted surfaces leave white specks.

Wood or metal surfaces can be sprayed and grain bins fogged with oil solutions of insecticides. Use a refined, deodorized oil to dilute oil concentrates. Most available oil solutions do not need to be diluted before use. They can be used near electrical switches. In cold weather, oil solutions are better than water-based sprays because they will not freeze. Avoid treating plastic or rubber surfaces with oil solutions.

Insects in floor and wall spaces can be controlled with insecticide powders or dusts, because these places are hard to treat with liquid insecticides. Use a dust applicator or sweep the dust into floor cracks.

Stored oilseeds absorb contact insecticides from treated granary surfaces. Therefore, avoid treating granaries in which oilseeds are to be stored. If the granary is known to be infested, sweep it well, destroy the sweepings, and treat sparingly only the junctions of the floor and walls.

If stored-product insects are visible on the outside wall of the granary, spray the walls and surrounding ground. Even if insects are not readily visible, it is a sound practice to spray grain spillage, the ground around the granary, and underneath raised granaries.

Cautions when you use sprays

- Read insecticide labels and follow instructions on them.
- Examine the sprayer and hoses for leaks.
- Avoid spillage of insecticide.
- Use a protective mask with approved filters when applying insecticide in enclosed areas such as empty granaries.
- Wear protective clothing, work boots, and gloves during preparation and spraying.

Dilution of concentrates

The amount of water needed to dilute emulsifiable concentrates or wettable powder formulations depends on the amount of insecticide in the concentrate and the dosage of insecticide recommended to control the pest. Use the following example to calculate how much water to add to a 50% emulsifiable concentrate in order to obtain a 2% spray:

$$(50-2)/2 = 48/2 = 24$$

Therefore, add 1 part (0.2 L) of a 50% emulsion to 24 parts (4.8 L) of water to obtain a 2% spray.

Fig. 5 shows how much water must be added to 1 part of emulsifiable concentrate or wettable powder concentrate to obtain a 0.5%, 1%, 2%, or 5% spray.

Some insecticides are more effective and longer lasting than others. Use a 1% spray to control rusty grain beetles in empty farm granaries and apply the insecticide about 5 days before filling the granary. Use a 5% spray for longer effectiveness if the granary is to be left empty for a month or two before harvest.

Apply the spray evenly with a portable compressed air sprayer at 5 L/100 m^2 using a nozzle with a 0.4-mm diameter orifice for emulsifiable concentrates or oil solutions and a 0.8–1.2-mm diameter orifice for wettable powder solutions.

The amounts of spray required to treat the floors and walls of granaries of various capacities are shown in Fig. 6.

Grain treatment

Special formulations of contact insecticides are available for treating grain as it is being binned. Either a liquid insecticide is sprayed on the grain or a dust is mixed with the grain at a certain rate, depending on the flow through the auger. Follow the instructions on the label. Overtreating the grain produces chemical odors that lower the selling price. Do not sell the grain or use it for feed during the post-treatment period specified on the label.

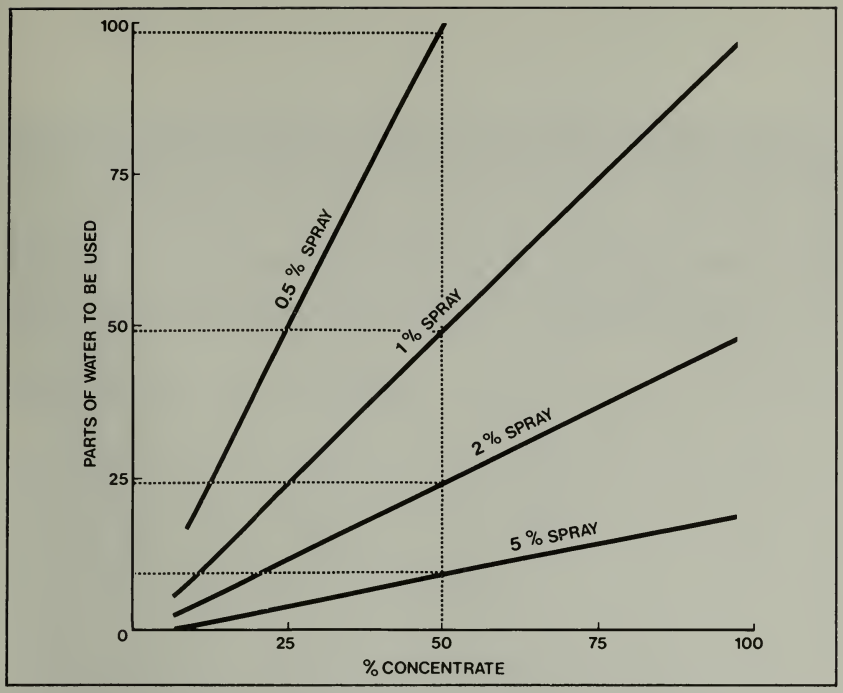


Fig. 5 Amount of water to be added to 1 part of concentrate to obtain sprays containing 0.5%, 1%, 2%, and 5% of actual insecticide.

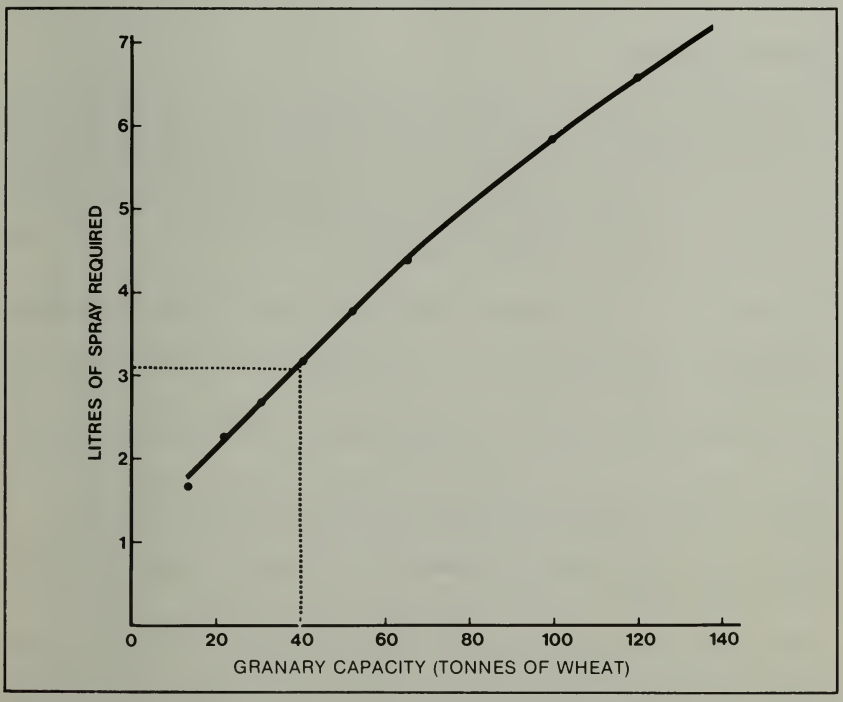


Fig. 6 Volume of spray needed to treat granaries of various capacities.

To treat the grain with a 1% spray of the recommended insecticide, apply it at 0.8 L/t of wheat. Use Table 2 to determine the amount and rate of insecticide application.

Table 2. Amount and rate of insecticide application

Flow rate (wheat)		Application rate (spray)	
Tonnes per hour	Tonnes per minute	Litres per hour	Litres per minute
3	0.05	2.4	0.04
6	0.10	4.8	0.08
9	0.15	7.2	0.12
12	0.20	9.6	0.16
15	0.25	12.0	0.20

The insecticide can be applied to grain either to protect it from infestation during storage or to control an infestation that is already in the grain. The treatment is more effective as a protectant, but the grain should be stored in good condition and contain less than 15% moisture, otherwise the insecticide will break down quickly, reducing its residual activity.

Grain fumigation

Fumigants are toxic gases that are sometimes used to control insects in stored grain. Fumigants are usually available as liquids or solids. They are toxic to humans and farm animals as well as to insects and, therefore, should be applied only by trained people. Avoid inhaling the vapors, and follow the directions on the container (see section on Cautions).

Fumigants should be applied only when:

- A person trained in their use is available to supervise the fumigation.
- The grain temperature is at least 5°C. Fumigants are most effective at temperatures higher than 20°C.
- The infested grain is stored in a granary that can be well sealed to retain the gas.
- Rapid control of an infestation is needed before selling the grain.
- Gas masks, rubber gloves, and protective clothing are available to wear during application.

There are two types of fumigants for treating farm-stored grain. Liquid fumigants can be sprayed on the grain surface, poured on the grain as it is binned, or poured down pipes inserted into the grain. Solid fumigants, in

the form of tablets or spherical pellets, can either be applied to the grain as it is binned or be inserted into the grain through pipes at the surface.

Before applying fumigants, seal building cracks, crevices, and other openings in the granary to prevent gas leakage. Fumigate the entire bulk by spraying liquid fumigant evenly over the surface, probing fumigant tablets or spherical pellets into the grain, or adding tablets, pellets, or liquid fumigant to the grain stream as it is discharged from an auger into another bin.

Surface sprays with fumigants

Tightly constructed metal bins require smaller dosages of fumigants than do wooden bins. Apply the fumigant as a coarse spray on the grain surface through an opening from outside the granary. Use a bucket pump for applying up to 50 L of fumigant per granary. For fumigating larger bulks of more than about 50 t, use a gear pump or other power-operated sprayer. A gear pump driven by a 2611-W (3.5-hp) gasoline engine will spray fumigant through a 3-cm diameter rubber hose at 30–50 L/min. Keep the fumigant, pump, and engine at ground level. Start spraying the grain at the far end of the granary and then gradually work toward the door.

Clean pumps thoroughly with a suitable solvent after they have been used for spraying fumigants.

Spot treatment

When the locations of infestations in grain are known, apply the fumigant directly to the infested regions. To apply liquid fumigants, use metal pipes 2–3 cm in diameter with 1-mm holes drilled in the bottom 30 cm. Insert the pipes in and around the infested areas and pour the fumigant into the pipes through a funnel.

Apply fumigant tablets or spherical pellets through a 1.5-m metal pipe 3 cm in diameter.

Grain treatment with solid fumigants

Apply tablets or pellets to stored grain in either of the following two ways:

(1) Drop them into the grain at uniform time intervals as the bin is being filled.

(2) Drop them through a metal pipe inserted into the grain. In a 27-t granary, for example, select about 12 evenly spaced points on the surface of the grain and mark the points with wooden stakes. Insert a pipe, 3 cm in diameter and 1.5 m long, at each point and drop a tablet into the grain every 15 cm as the pipe is withdrawn. Start at the far end of the bin and work toward the door.

Fig. 7 Fumigating the grain: *A*, fumigant being poured into can containing bucket pump; *B*, spraying fumigant on the surface of stored grain; *C*, spot fumigating an infested pocket of wheat with liquid fumigant; and *D*, spot fumigating an infested pocket with aluminum phosphide tablets.

Cautions

When you use fumigants, follow the directions on the label closely and especially take the following precautions:

- Always wear a full-face gas mask.
- Always fit a new canister in your gas mask before you start fumigating. Use the type of canister recommended on the fumigant label for the fumigant you are using. An all-purpose canister is suitable for protection against most commonly used grain fumigants, but a canister does not provide protection for people exposed to heavy concentrations inside buildings.
- Whenever possible, apply liquid fumigants from outside a granary as quickly as possible to avoid excessive personal exposure.
- Always work with at least one other person.
- Wear rubber gloves and a hard hat.
- If the fumigant spills on your clothing, remove the article immediately.
- If an individual shows symptoms of overexposure to a fumigant, that person should be moved to fresh air and a doctor called immediately. Symptoms of fumigant poisoning are dizziness, blurring of vision, vomiting, and abdominal pain.
- After fumigating a granary, nail or lock the doors and ventilators and post warning signs on the door.
- After a week, open the ventilators, but do not enter the granary until there is no odor. Because fumigated grain can take several weeks to aerate during cold weather, be careful not to inhale the gases.
- Do not feed fumigated grain to cattle unless the grain has been completely aerated and is odorless.
- Always consider wind direction. If there is a habitation occupied by humans or livestock close to and downwind from the structure to be fumigated, postpone the fumigation until the wind dies down or changes direction.
- Do not fumigate when there are strong winds.
- For your safety, position yourself upwind during application of fumigant to grain being augered into a bin. Avoid standing downwind from a bin under fumigation.

MORE INFORMATION

If you need more information on the control of infestations in farm-stored grain, write to the Research Station, Agriculture Canada, 195 Dafoe Road, Winnipeg, Man. R3T 2M9; provincial entomologists; or provincial extension specialists.

Note: The recommendations in this publication apply generally to other parts of Canada where grain is grown and stored. The European grain moth, *Nemapogon granella* (Linnaeus), has not been found in the prairie region but has been reported from Eastern Canada.

ACKNOWLEDGMENTS

The authors wish to thank R. W. Sims for the photographs and illustrations, and J. van Loon, Canadian Grain Commission, for reading and reviewing the French edition of this publication.

COMMON AND SCIENTIFIC NAMES OF PESTS IN STORED GRAIN

American black flour beetle	*Tribolium audax* Halstead
cannibal mite	*Cheyletus eruditis* (Schrank)
confused flour beetle	*Tribolium confusum* Jacquelin du Val
foreign grain beetle	*Ahasverus advena* (Waltl)
glossy grain mite	*Tarsonemus granarius* Lindquist
grain mite	*Acarus siro* Linnaeus
granary weevil	*Sitophilus granarius* (Linnaeus)
hairy spider beetle	*Ptinus villiger* (Reitter)
longhaired mite	*Lepidoglyphus destructor* (Schrank)
meal moth	*Pyralis farinalis* Linnaeus
psocids	*Lepinotus reticulatus* Enderlein and other species.
red flour beetle	*Tribolium castaneum* (Herbst)
rice weevil	*Sitophilus oryzae* (Linnaeus)
rusty grain beetle	*Cryptolestes ferrugineus* (Stephens)
sawtoothed grain beetle	*Oryzaephilus surinamensis* (Linnaeus)
squarenosed fungus beetle	*Lathridius minutus* (Linnaeus)
yellow mealworm	*Tenebrio molitor* Linnaeus

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2.5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre